

This invention relates to an apparatus for processing a semiconductor in an atmosphere separated from the air, and particularly to a semiconductor processing apparatus suitable for processing a semiconductor wafer by plasma processing.

In plasma processing semiconductor producing apparatuses such as a plasma etching apparatus, a plasma chemical vapor deposition apparatus, etc., electric current, voltage and temperature of wafer at plural points distributed on the surface of a wafer to be processed during semiconductor processing process and their distribution are remarkably important parameters in the semiconductor producing process. Therefore, in order to produce semiconductors in high precision, high efficiency and stably, to measure these values precisely before the processing becomes an important factor.

Heretofore, for such purposes, there have
20 been proposed various sensor probes, some of which are
practically used. Among them, there is a sensor module
with a wafer shape equipped and used in a place where a
wafer to be processed is positioned in a semiconductor
processing apparatus. Such a sensor module is called
25 in various ways, but in the present invention, it is

One example of known wafer sensor modules is disclosed in JP-A-8-213374 as "diagnostic wafer", which is fundamentally formed by an aluminum circular plate subjected to anodic treatment, and comprises an ion current probe, a main portion of which is placed on a wafer, and an ion energy analyzer.

15 According to the known wafer sensor module
such as the above-mentioned "diagnostic wafer", since
it is electrically connected in the semiconductor
producing apparatus and also connected to the outside,
it is necessary to carry out connection working and
20 dismantle working of electric wiring at the time of
setting up and removal thereof.

Since the interior of the semiconductor producing apparatus is separated from the air, when the wafer sensor module is used, it is necessary to take out electric signals from the apparatus to the outside. According to the prior art technology, since electric wiring (a conducting wire) is used for transmission of electric signals, it is necessary to take out the

In order to take out the electric wiring from the place separated from the air, there have been used a method wherein a part called a current introducing terminal (or a penetrating terminal) is equipped in a through hole formed at a vacuum partition, and each electric wiring is connected to the current introducing terminal from the vacuum side and the air side, or a method wherein the periphery of electric wiring

10 penetrating a through hole formed at a vacuum partition
is sealed with an elastomer (e.g. a sealing material
such as silicone rubber).

15 sealing treatment at the time of setting up and removal of the wafer sensor module. Thus, it is necessary to make the processing chamber open after stopping the semiconductor processing and producing apparatus temporarily, resulting in lowering the throughput.

20 Here, the measurement by means of the wafer
sensor module is carried out before the beginning of
the use of semiconductor producing apparatus, but if
necessary, the measurement should be conducted with the
predetermined frequency, for example, when the
25 processing number of semiconductor wafers become a
predetermined number. As a result, according to the
prior art technology, the throughput is lowered as
mentioned above.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to provide a semiconductor processing apparatus which can set up and remove a wafer sensor module without opening
5 the processing chamber, and a wafer sensor module used in said apparatus.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken
10 in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatic view for explaining one embodiment of the semiconductor wafer processing apparatus of the present invention.

15 Fig. 2 is a plan view of one embodiment of wafer sensor module of the present invention.

Fig. 3 is an enlarged cross-sectional view of a sensor probe portion of one embodiment of wafer sensor module of the present invention.

20 Fig. 4 is an enlarged cross-sectional view of voltage sensor probe in one embodiment of the present invention.

Fig. 5 is an enlarged cross-sectional view of voltage sensor probe in another embodiment of the
25 present invention.

Fig. 6 is an enlarged cross-sectional view of current sensor probe in one embodiment of the present

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invention.

Fig. 7 is an enlarged cross-sectional view of temperature sensor probe in one embodiment of the present invention.

5 Fig. 8 is a diagrammatic view for explaining another embodiment of the semiconductor wafer processing apparatus of the present invention.

Fig. 9 is a diagrammatic view for explaining further embodiment of the semiconductor wafer
10 processing apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The above-mentioned object of the present invention can be attained by an apparatus for processing a semiconductor, which comprises
15 an airtight processing chamber separated from the air,

a stage installed in the chamber, and
a wafer sensor module equipped with sensor probes, each sensor probe capable of detecting at least
20 one of electric current passing through an article to be processed, voltage and temperature, said wafer sensor module positioned on the stage after carried in the processing chamber by a transporting means for the article (semiconductor wafer) to be treated.

25 At this time, the above-mentioned object can also be attained by the apparatus wherein measured values detected by the sensor probes are converted to

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optical signals, which are lead out from the wafer sensor module to the outside of the processing chamber.

The above-mentioned object can further be attained by the apparatus wherein the optical signals
5 are received by a means for receiving optical signals equipped on the stage.

In addition, the above-mentioned object can be attained by the apparatus wherein the stage has a means for applying an optional voltage to at least one
10 point of the wafer sensor module.

Further, the above-mentioned object can be attained by the apparatus wherein the means for receiving optical signals processes at least two optical signals caused by measured values in common and
15 leads to outside of the semiconductor processing apparatus.

The present invention also provides a wafer sensor module comprising a silicon substrate as a main body, and at least one sensor probe and a luminescent
20 device formed thereon.

In the above-mentioned wafer sensor module, the silicon substrate as a main body has almost the same shape as a semiconductor wafer to be processed.

The semiconductor processing apparatus of the
25 present invention is explained in detail referring to embodiments of the drawings.

Fig. 1 is a diagrammatic view for explaining

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5 processing. In the vacuum container, the air is exhausted to obtain vacuum, then a suitable processing gas is introduced thereinto to generate plasma (not shown in the drawing) in the processing chamber C using a plasma generating device (not shown in the drawing).

Bias voltage is applied from a bias power source (not shown in the drawing) to the wafer stage 200, and by this the plasma generated in the processing chamber C is drawn in the direction of the wafer stage 200.

In the embodiment of Fig. 1, numeral 100

denotes a wafer sensor module which has almost the same size as the semiconductor wafer to be processed and positioned on the wafer stage 200. The semiconductor wafer to be processed (not shown in the drawing) is to
5 be positioned in exchange of the wafer sensor module 100.

In Fig. 1, numeral 101 denotes a sensor probe, numeral 102 denotes a luminescent device, and numeral 201 denotes a receiving optics.

10 The sensor probes 101 are positioned on the surface of the wafer sensor module 100 in a plural number with a predetermined pattern as shown in Fig. 2. Each sensor probe can measure at least one of ion current, voltage distribution and temperature as an
15 object to be measured.

Individual luminescent devices 102 are positioned on a rear side of the wafer sensor module 100 so as to be combined with individual sensor probes 101 and placed in the same positions as the sensor
20 probes 101, respectively, when viewed from above the drawing. Each luminescent device 102 is connected to corresponding sensor probe 101, and emits light of which wavelength is depending on measured values of current, voltage distribution, temperature, etc.
25 detected by or with the each sensor probe 101.

Thus, the wafer sensor module 100 has a shape of circular plate as a main body on one side of which is buried each sensor probe 101 and on another side of

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which is buried each luminescent device 102,
respectively. As the main body, there can be used, for
example, a silicon plate.

On the other hand, in Fig. 1, numeral 201
5 denotes a light receiving portion, which is positioned
opposite to each luminescent device 102 when the wafer
sensor module 100 is positioned on the upper side of
the wafer stage 200, and functions so as to collect and
take in the light generated by each luminescent device
10 102 effectively. Thus, the light receiving portion is
constructed by a lens having a predetermined size.

Numeral 202 denotes a light guide, which
functions to lead out the light taken in each light
receiving portion 201 to the outside independently.
15 Thus, each upper end of vertical portion of the light
guide in the wafer stage 200 is connected to respective
light receiving portion 201. The light guide is made
of, for example, an optical fiber having a
predetermined diameter and positioned in the wafer
20 stage 200 so as to lead out the light independently
outside of the vacuum container 400.

In Fig. 1, numeral 300 denotes a conversion
device which is equipped with a light receiving portion
connected to light lead-out end of respective light
25 guide 202 and functions to convert the light led out
from each light guide 202 to a predetermined voltage
depending on the wavelength of light.

Next, operation of the semiconductor

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processing apparatus of the present invention is explained referring to one embodiment of Fig. 1.

In this semiconductor processing apparatus, first, a wafer sensor module 100 is previously prepared
5 depending on the kind of semiconductor wafer to be processed and the kind of processing to be conducted. The wafer sensor module 100 to be prepared is one having sensor probes 101 with a predetermined number and a predetermined pattern depending on for detecting
10 current, detecting voltage, detecting temperature, etc. necessary for the semiconductor wafer.

Before starting the processing of semiconductor wafer, the wafer sensor module 100 is first carried in the processing chamber C by the wafer
15 transporting system 500 and positioned on the wafer stage 200. At this time, each luminescent device 102 on the under side of wafer sensor module 100 is placed so as to be opposite to each light receiving portion 201 on the upper side of the wafer stage 200.

20 As explained above, the wafer sensor module 100 has almost the same size as the semiconductor wafer, which is carried by the wafer transporting system 500. Thus, the transportation of the wafer sensor module 100 by the wafer transporting system 500
25 can be carried out in the same manner as the semiconductor wafer with precisely and easily.

As a result, it is not necessary to conduct working of connection of wires to sensors, etc. and

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5 As a result, ion current passes through the wafer sensor module 100, voltage generates on the wafer sensor and temperature of the wafer sensor changes, and these are detected by sensor probes 101, respectively, to make each luminescent device 102 emit light.

By measuring the voltage output from the conversion device 300, the ion current, voltage distribution and temperature can be recognized to obtain necessary data for setting necessary processing conditions. As a result, it is possible to contribute for carrying out suitable processing of the semiconductor wafer hereinafter. Therefore, according to this embodiment, very high throughput in the processing of semiconductor wafers can always be maintained without fail.

Then, details of the wafer sensor module 100 are explained below.

Positions of each sensor probe 101 are crosswise in Fig. 2, but not limited thereto. In the
5 case of Fig. 2, ion current, voltage distribution and temperature at the position of each sensor probe 101 can be measured.

The positions, numbers and positional pattern of individual sensor probes 101 can be set optionally
10 and can be changed depending on necessity. For example, it is possible to take a lattice-like pattern, a concentric circle pattern, or the like. As to the plasma processing, when the plasma distribution is regarded as symmetrical as to the center axis, it is
15 sufficient to position only on a radius.

Next, details of the sensor probes 101 are explained below. The sensor probes including the main body of the wafer sensor module 100 can be made of single crystal silicon wafer as a raw material.

20 Reasons for employing the single crystal silicon wafer as the raw material are as follows.

The single crystal silicon wafer is supplied for producing semiconductors with relatively cheap and in a large amount. Further, since it is the same as
25 the material worked practically in the semiconductor producing process, special attention for handling, and the like is not necessary, and various devices can easily be formed by similar process for producing

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semiconductors and already established dry and wet etching steps and film forming steps, so that facilities are very high.

Fig. 3 shows another embodiment of the wafer sensor module 100, wherein as each sensor probe 101, 3 kinds of current sensor probe 1011, voltage sensor probe 1012 and temperature sensor probe 1013 are formed on upper side of the wafer sensor module 100.

The voltage sensor probe 1012 are formed of electrode 1014, light emitting diode (LED) 1015 connected to one terminal of the electrode 1014, and reference electrode 1016 connected to another terminal of the LED 1015 as shown in Fig. 4. In this case, the reference electrode 1016 is formed with a predetermined distance from the electrode 1014.

The LED 1015 is made of an assembly of plural different LED having known threshold voltage, so that color properties obtained by light emission are different each other. Thus, by this, lights with different colors are emitted depending on voltage difference between the electrode 1014 and reference electrode 1016.

The light emitted from the LED 1015 is received by the opposite light receiving portion 201 on the wafer stage 200 side, followed by passing through the light guide 202 to the outside of the semiconductor producing apparatus and input to the conversion device 300.

The conversion device 300 is a device for converting optical signals to electric signals, and outputs predetermined voltage signals depending on the color of light input. From the correspondence of
5 voltage of this signal to the known threshold voltage of LED, the conversion device can display a voltage difference between the electrode 1014 and the reference electrode 1016 in an indicator (not shown in the drawing).

10 Fig. 5 shows another embodiment of the voltage sensor probe 1012. As shown in Fig. 5, a contact pin 203 which penetrates the wafer stage 200 to contact with the reference electrode 1016, can give optional known voltage to the reference electrode 1016
15 from the outside. According to this embodiment, it is possible to measure an absolute voltage of the electrode 1014.

Next, the current sensor probe 1011 shown in Fig. 3 is explained below, although not in order. The
20 current sensor probe 1011 is formed of the reference electrode 1016, electrode 1017, resistor 1018 and LED 1019 as shown in Fig. 6. The reference electrode 1016 is contacted with the contact pin 203 in the wafer stage 200 side like the case of the voltage sensor
25 probe shown in Fig. 5.

The resistor 1018 has a known resistance value and connected to the LED 1019 in parallel between the electrode 1017 and the reference electrode 1016.

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Fig. 3 is explained. This is obtained by only burying a phosphor 1020 in a predetermined place of the wafer sensor module 100. The phosphor 1020 is a fluorescent substance which emits specific fluorescence at a
5 specific temperature.

Therefore, by inputting the fluorescence emitted from the phosphor 1020 to the conversion device 300 via the light receiving portion 201 and the light guide 2002, it is possible to display the temperature
10 of the position wherein the phosphor 1020 is set in the indicator not shown in the drawing.

As mentioned above, by any of the wafer sensor module 100 explained in Figs. 3 to 7, it is possible to measure the current, voltage and
15 temperature of the semiconductor wafer easily by only positioning the wafer sensor module on the wafer stage 200 without operation of changing connection of wires.

Next, another embodiment of the present invention is explained below. Fig. 8 shows a second
20 embodiment of the present invention, wherein the light receiving device 301 is provided on a side wall of the vacuum container 400 and can detect lights emitted from respective sensor probes 101 of the wafer sensor module 100. Other constitution including the vacuum container
25 400 is the same as that of Fig. 1, but the wafer transporting system 500 is omitted for simplification.

In this embodiment, the fundamental constitution of the wafer sensor module 100 per se is

the same as the wafer sensor module 100 explained in Figs. 1 to 7. In the embodiment of Fig. 8, one different point is that each luminescent device of sensor probe 101 is positioned on the upper side of the
5 wafer sensor module. In this case, each LED and phosphor constituting each luminescent device is designed to emit different color of light.

More concretely, in the case of current sensor probe, it is designed to emit individually in
10 the red region in the visible light range, in the case of voltage sensor probe, it is designed to emit individually in the green region, and in the case of temperature sensor probe, it is designed to emit individually in the blue region.

15 In compliance with this, the light receiving device is designed to detect light intensity individually in each color region in the visible light range. In this case, it is also designed to select individually sensor probes 101 and to take in the light
20 therefrom preponderantly from whole the surface of the wafer sensor module 100 as shown in Fig. 8. For such a purpose, it is possible to use a television camera, or to use a light receiving device limited in the field of vision to the size of individual sensor probe 101 and
25 scanning whole surface of the wafer sensor probe 100 as to the light receiving axis.

Each light emitted from each sensor probe 101 is received by the light receiving device 301 and input

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to the conversion device 300. As a result, it is possible in this embodiment to recognize the current, voltage and temperature detected by each sensor probe 101 at the outside. Thus, according to this

5 embodiment, it is also clear that only by positioning the wafer sensor module 100 on the wafer stage 200 by the wafer transporting system 500, the measurement of current, voltage and temperature of the semiconductor wafer becomes possible easily without operation of

10 changing wires for connection, and the like.

In the embodiment of Fig. 8, since the plasma is directly irradiated on the wafer sensor module 100 positioning the sensor probes 101, the light from the plasma is also received by the light receiving device

15 301. In order to remove influence of the light of plasma, it is necessary to intercept the plasma light by using, for example, a band-pass filter, etc. not shown in the drawing. Further, in order to minimize damages of the sensor probes 101 caused by the plasma,

20 it is desirable to provide a protective means for the sensor probes 101 of the wafer sensor module 100.

Further, in the case of the embodiment of Fig. 8, since it is not necessary to provide a light receiving portion and a light guide such as optical

25 cable, etc., there is no fear of making the constitution of wafer stage complicated, resulting in providing advantages such as degree of freedom of design being heightened, application to conventional

apparatuses becoming easy and the like.

Fig. 9 shows a third embodiment of the present invention. In this embodiment, individual luminescent devices 102 in the embodiment of Fig. 1 are
5 collected to one place in a sheet of wafer sensor module 100. In compliance with this, the light receiving portion 201 is collected to one place on the wafer stage 200 side. The received light is led to the conversion device 300 via one light guide 202.

10 At least one detected value selected from current, voltage and temperature detected by each sensor probe 101 is converted to light signals having different colors, so that even if the light signals were collected by the light receiving portion 201 and
15 input to the conversion device 300 via one light guide 202 in common, it is possible to separate the light signals to those from individual sensor probes 101 by using a filter.

Thus, according to this embodiment, it is
20 also possible only by positioning the wafer sensor module 100 on the wafer stage 200 by the wafer transporting system 500, the measurement of current, voltage and temperature of the semiconductor wafer becomes possible easily without operation of changing
25 wires for connection, and the like.

Further, in the case of using the wafer sensor module 100 of Fig. 9, since the number of light receiving portion and the number of light guide

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positioned in the wafer stage 200 can be minimized,
there can be obtained advantages such as degree of
freedom of design being heightened, application to
conventional apparatuses becoming easy and the cost as
5 a system being able to be reduced, and the like.

In the above embodiments, LED and phosphors
are used as the sensor probe 101, but it is also
possible to use a structure which can be changed
mechanically by at least one of current, voltage and
10 temperature as the sensor probe, and to measure the
changed amount by means of an optical means for
recognition in order to practice the present invention
and to attain the objects of the present invention.

According to the present invention, since the
15 voltage and voltage distribution in an article to be
processed, the current passing through the article to
be processed, and the temperature of the article to be
processed in the semiconductor wafer processing
apparatus can be measured easily and simply without
20 lowering the throughput, it is possible to optimize
conditions necessary for processing semiconductor
wafers sufficiently with ease in a short time.

It should be further understood by those
skilled in the art that the foregoing description has
25 been made on embodiments of the invention and that
various changes and modifications may be made in the
invention without departing from the spirit of the
invention and the scope of the appended claims.

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